Pacific Northwest NATIONAL LABORATORY

PNNL-34856

Intermediate Temperature Single Component Electrolysis Cell

September 2023

Evgueni Polikarpov

U.S. DEPARTMENT OF ENERGY

Prepared for the U.S. Department of Energy
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Abstract

This project aims at demonstrating a fundamentally new approach towards electrochemical hydrogen production using a single component cell design. Conventional electrolyzer cells consist of a stack of layers (oxygen and fuel electrodes, electrolyte layer) that require multiple processing steps and add to the fabrication cost and complexity. Here we explore the viability of a single-layer electrolyzer device based on the single-layer SOFC concepts described in literature (Asghar et al, 2020). The single layer material is a composite of ionic conductor and catalytic material consisting of ceria doped with Gd and Sm co-processed with $CuFe_2O_4$ nanopowder.

Summary

Evaluation of the single-component electrolyzer cell concept involves design and synthesis of the active layer material, fabrication of the device, testing the device in an fuel cell mode (to replicate the cell performance data reported in the literature), and testing the cell in the reverse mode to evaluate its viability as an electrolyzer that produces hydrogen. We have not been able to replicate the synthetic procedures reported in (Asghar et al, 2020). Alternative synthetic routes have been explored with promising results on small scale. 1 g of the active material composite CeO_2/Gd/Sm/$CuFe_2O_4$ has been synthesized, and the synthesis is being scaled up. The scaleup will be followed by the device fabrication and testing in the fuel cell and electrolyzed modes.

Acknowledgments

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Acronyms and Abbreviations

SOFC – Solid Oxide Fuel Cell

SOEC – Solid Oxide Electrolysis Cell

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1.0 Introduction

Hydrogen as an energy carrier and storage option is attracting increased attention as an alternative to fossil fuels. The electrolysis of water is one of the potential technologies of hydrogen production. The focus on this work will be on the solid oxide electrolysis cells (SOEC). Typical SOECs are characterized by high operation temperatures necessary for reducing ohmic losses in the electrolyte, which has been one of the barriers to widespread commercialization. Multilayer cell architectures tend to suffer from mismatches in thermal expansion behavior between the different layers, delamination, fracture, and costly processing steps. Replacement of the multilayer structures with a single-layer design has potential to address these problems. This project aimed at examining a single component electrolysis cell that excludes the traditional electrolyte. This approach will allow for operation at intermediate temperature (400-500°C) and low-cost manufacturing. Figure 1 illustrates the principles of operation and the differences between the multilayer and single-layer electrolyzer cells:

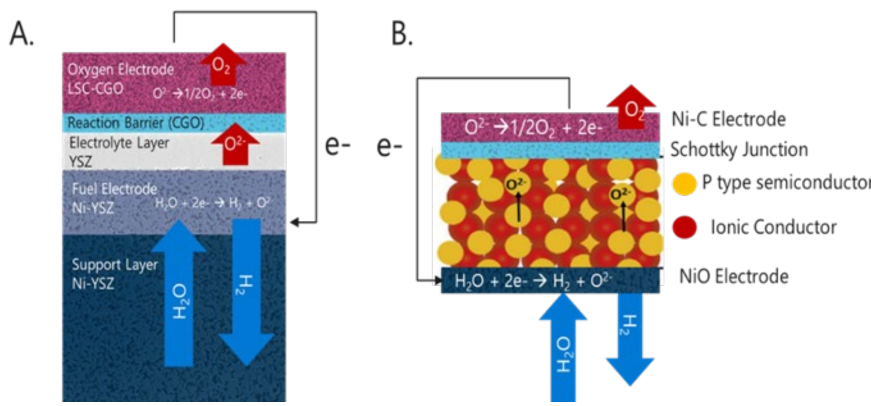

Figure 1. Comparison of conventional three-layer solid oxide electrolyzer (A) with single component electrolyzer (B) that utilizes intrinsic p-type semiconducting materials to form a Schottky junction that inhibits electronic shorting and losses, adapted from (Asghar et al 2020).

The aim of this project was to build and test a single component electrolysis cell with a structure similar to the structure shown in Figure 1B, using the PNNL ceramic synthesis and device fabrication and testing capabilities. This work will lay the foundation for further device optimization to achieve high performance and high efficiency electrolysis.

2.0 Results and Discussion

An attempt to replicate the sol-gel synthesis following the procedure published in (Asghar et al 2020) was carried out by two different chemists. In either case, the attempt to replicate the procedure wasn't successful. The formation of gel as an intermediate of the reaction between Gd, Sm, and Ce nitrates the way it was described in literature could not be achieved.

Next, several attempts at optimization of the sol-gel approach were undertaken, for example excluding polyethylene glycol from the reaction procedure, replacing polyethylene glycol with ethylene glycol, and using polyvinylpyrrolidone as an auxiliary gelating reagent. None of these modifications produced the desired product. More success has been achieved by switching from the sol-gel to hydrothermal method. 1 gram of the target intermediate Gd,Sm-doped ceria was synthesized this way. The intermediate was blended with $CuFe_2O_4$ nanopowder, sintered at 700°C followed by vigorous grinding for 30 minutes. The amount of the target material needed for the fabrication of the device significantly exceeds the results of the trial run, and the scaleup is currently underway.

Once sufficient quantities of the material are synthesized using the newly developed method, it will be used for device fabrication and testing.

Exploration of other single-layer SOEC material compositions alternative to that of published in (Asghar et al 2020) is also being undertaken at the time of this writing.

3.0 References

Asghar, M. I., X. Yao, S. Jouttijärvi, E. Hochreiner, R. Virta, and P. D. Lund. 2020. "Intriguing electrochemistry in low-temperature single layer ceramic fuel cells based on CuFe2O4." International Journal of Hydrogen Energy 45, no. 45: 24083-24092.

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